Renewable and Sustainable Energy Reviews 14 (2010) 2906–2915

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Forecasting of CO_2 emissions from fuel combustion using trend analysis

Aylin Çiğdem Köne [a], Tayfun Büke [b,*]

[a] Muğla University, Faculty of Economics and Administrative Sciences, Department of Economics, 48000 Muğla, Turkey
[b] Muğla University, Faculty of Arts and Sciences, Department of Physics, 48000 Muğla, Turkey

ARTICLE INFO

Article history:
Received 12 May 2010
Accepted 10 June 2010

Keywords:
CO_2 emissions
Trend analyses
Forecasting

ABSTRACT

The accelerating use of fossil fuels since the Industrial Revolution and the rapid destruction of forests causes a significant increase in greenhouse gases. The increasing threat of global warming and climate change has been the major, worldwide, ongoing concern especially in the last two decades. The impacts of global warming on the world economy have been assessed intensively by researchers since the 1990s. Worldwide organizations have been attempting to reduce the adverse impacts of global warming through intergovernmental and binding agreements. Carbon dioxide (CO_2) is one of the most foremost greenhouse gases in the atmosphere. The energy sector is dominated by the direct combustion of fuels, a process leading to large emissions of CO_2. CO_2 from energy represents about 60% of the anthropogenic greenhouse gas emissions of global emissions. This percentage varies greatly by country, due to diverse national energy structures. The top-25 emitting countries accounted 82.27% of the world CO_2 emissions in 2007. In the same year China was the largest emitter and generated 20.96% of the world total. Trend analysis is based on the idea that what has happened in the past gives traders an idea of what will happen in the future. In this study, trend analysis approach has been employed for modelling to forecast of energy-related CO_2 emissions. To this aim first, trends in CO_2 emissions for the top-25 countries and the world total CO_2 emissions during 1971–2007 are identified. On developing the regression analyses, the regression analyses with R^2 values less than 0.94 showing insignificant influence in statistical tests have been discarded. Statistically significant trends are indicated in eleven countries namely, India, South Korea, Islamic Republic of Iran, Mexico, Australia, Indonesia, Saudi Arabia, Brazil, South Africa, Taiwan, Turkey and the world total. The results obtained from the analyses showed that the models for those countries can be used for CO_2 emission projections into the future planning. The calculated results for CO_2 emissions from fitted curves have been compared with the projected CO_2 emissions given in International Energy Outlook 2009 of U.S. Department of Energy calculated from "high economic growth case scenario", "reference case scenario" and "low economic growth case scenario" respectively. Agreements between calculated results and the projected CO_2 emissions from different scenarios are in the acceptable range.

Contents

1. Introduction

Environmental problems encompass a continuously growing array of pollutants and ecosystem degradation. The environmental impact of human activities has grown dramatically because of the sheer increase of world population, energy consumption, industrial activities, urbanisation, etc. Energy use in various forms plays a critical role in affecting local environment and global climate change. The growing environmental degradation observed at the local, national and global level attracted the concern of energy analysts and policy makers towards the environmental side effects of energy use and related social welfare. Policies for reducing energy

* Corresponding author. Tel.: +90 252 211 1593; fax: +90 252 211 1472.
E-mail address: tbuke@mu.edu.tr (T. Büke).

1364-0321/$ – see front matter
doi:10.1016/j.rser.2010.06.006

use alone may not be enough to ensure a certain desired level of environmental quality along with a desired level of economic growth and social welfare. The qualitative dimension of energy use is becoming increasingly important for sustainable development. One important question in this context and in the context of global climate change is how one can achieve the separation of greenhouse gas emissions [1]. The primary greenhouse gas emitted through fuel combustion is CO_2. CO_2 produced in combustion is perhaps not strictly a pollutant (being a natural product of all combustion); nonetheless it is of great concern in view of its impact on global warming. It is a stable molecule with less than 10 years average residence time, i.e. 3 years in the troposphere, though its residence time is over 100 years in the atmosphere, and its present concentration in the atmosphere is increasing at an astonishing rate of 0.4% per year. The average residence time in the troposphere means the number of years a molecule exists before it is reused by another biological process on the earth's surface or broken apart in the stratosphere [2,3]. Dunn and Flavin have been stated that CO_2, which is released into the atmosphere from the burning of fossil fuels, is the single most important greenhouse gas contributing to the "anthropogenic forcing of climate change" in the northern hemisphere [4]. Thus, they conclude the share of CO_2 in warming is expected to rise from slightly more than half today to around 3/4th by 2100 and further stated that the average global surface temperature would be raised more during the 20th century than during any other century in the last 1000 years. CO_2 comprises about 0.03% of the earth's atmospheric volume, but due to the fossil fuel combustion and deforestation, this percentage has increased by about 25% since preindustrial times. The projected studies showed that excessive CO_2 emissions into the atmosphere will increase the earth's surface temperature approximately 1.5–4 °C in the next 30–40 years [5,6].

The top-25 CO_2 emitting countries accounted 82.27% of the world CO_2 emissions in 2007. In the same year China was the largest emitter and generated 20.96% of the world total. World total CO_2 emissions are increased to 28,962 Mtonnes of CO_2 in 2007 (Table 1) [7]. Projections by the International Energy Outlook 2009 have indicated that global CO_2 emissions in the world would increase to 33,111 and 40,385 million tones in 2015 and 2030 respectively according to the reference scenario [8].

Industrialized countries have the highest CO_2 emission levels, and must shoulder the greatest responsibility for global warming. However, action must also be taken by developing countries to avoid future increases in emission levels as their economies develop and populations grows, as clearly captured by the Kyoto Protocol [9]. According to the agreed targets within the framework of the Kyoto Protocol, total emissions of greenhouse gases (GHG) in developed countries during the first commitment period (2008–2012) must be reduced by at least 5% below 1990 levels [10–12]. The Kyoto Protocol can be cited as the most important agreement that tries to limit the countries' emissions within a time horizon. In this context, CO_2 emissions of many countries or regions of the world have been investigated in the literature. Sun showed an alternative viewpoint on the forecasting of energy-related CO_2 emissions in the OECD countries [13]. Energy consumption and CO_2 emissions have been estimated by data envelopment analysis in countries of the Middle East and North Africa [14].

The main features of CO_2 emission from fossil energy combustion are identified in China. Then China's future energy requirements and CO_2 emissions are estimated by the scenario analysis approach [15]. Electricity consumption and CO_2 capture potential in Spain are estimated for nine future scenarios [16]. CO_2 emissions in Greece are analysed by decomposition analysis and comparison of results using the Arithmetic Mean Divisia Index and Logarithmic Mean Divisia Index techniques during 1990–2002 [17]. CO_2 emissions of the Indian economy have been analysed by producing sectors and due to household final consumption. The analysis is based on an Input–Output (IO) table and Social Accounting Matrix (SAM) for the year 2003–2004 that distinguishes 25 sectors and 10 household classes [18]. On the other hand, in the International Energy Outlook 2009, CO_2 emissions by the countries are projected for five different cases namely high economic growth case, reference case, low economic growth case, high oil price case, low oil price case. Projected CO_2 emissions are strongly depends on macroeconomic growth cases for each case. Therefore, projected CO_2 emissions for each case are estimated different from each other for each case [8].

Table 1
CO_2 emissions by countries (2007).

Rank	Country	CO_2 emission (Mtonnes)	Total (%)
1	China	6071.2	20.96
2	United States	5769.3	19.92
3	Russian Federation	1587.4	5.48
4	India	1324.0	4.57
5	Japan	1236.3	4.27
6	Germany	798.4	2.76
7	Canada	572.9	1.98
8	United Kingdom	523.0	1.81
9	South Korea	488.7	1.69
10	Islamic Republic of Iran	465.9	1.61
11	Mexico	437.9	1.51
12	Italy	437.6	1.51
13	Australia	396.3	1.37
14	Indonesia	377.2	1.30
15	France	369.3	1.28
16	Saudi Arabia	357.9	1.24
17	Brazil	347.1	1.20
18	South Africa	345.8	1.19
19	Spain	344.7	1.19
20	Ukraine	314.0	1.08
21	Poland	304.7	1.05
22	Taiwan	276.2	0.95
23	Turkey	265.0	0.91
24	Thailand	225.7	0.78
25	Kazakhstan	190.5	0.66
	World total	28,962	100

In forecast modelling, as indicated in the literature [19–24], various methodologies can be used for energy production and consumption projections such as trend analysis, sector-specific econometric multiple-correlation forecasts, macroeconomic or input–output-based forecasting models, and surveys.

In the present modelling, trend analysis, which is the most common approach [2,25–27], is used to predict CO_2 emissions. The main advantage of this approach is its simplicity, and projections are based on whatever data are available. The other techniques are much more complicated and need many parameters.

In this study, trend analysis approach has been employed for modelling to forecast of energy-related CO_2 emissions. To this aim first, trends in CO_2 emissions for the top-25 countries and the world total CO_2 emissions (Table 1) during 1971–2007 are identified. CO_2 emissions data from 1971 to 2007 (see Table 2) are taken from Annual Historical Series of International Energy Agency [7]. These data were regressed for against the year using a least squares technique. On developing the regression analyses, the regression analyses with R^2 values less than 0.94 showing insignificant influence in statistical tests have been discarded.

Statistically significant trends are indicated for eleven countries and world total. The results obtained from the analyses showed that the models for those countries can be used for CO_2 emission projections into the future planning. The calculated results for CO_2 emissions from fitted curves have been compared with the projected CO_2 emissions calculated from "high economic growth case scenario", "reference case scenario" and "low economic growth case scenario" [8] respectively.

The rest of the study is organized as follows. Section 2 introduces CO_2 emission statistic analysis. Section 3 describes

regression analysis for future projections. Section 4 describes CO_2 emissions reductions. Finally, Section 5 gathers the main conclusions derived from this paper.

2. CO_2 emission statistic analysis

Trend analysis is an aspect of technical analysis that tries to predict the future movements based on past data. It mainly deals with the recognition and measurement of trends that can be represented by lines or surfaces. Trend analysis is almost invariably used anytime when the factor under investigations is quantitative [28]. The main goal is to determine an equation given in the below:

$$y = \sum_{i=0}^{n} a_n x^n \tag{1}$$

where a_n are coefficients; y is the CO_2 emission in year x. As the power n is increased, the actual behaviour of the data could be more and more closely represented. Although this approach is suitable for interpolation, the equation cannot be used for determining values beyond the extrapolation. For projecting the historical data past the end points into the future, some of the terms of power 2 and higher in Eq. (1) can vary wildly both in mark and in magnitude over only one year. Therefore such a general power series representation is not of interest. The projections can be carried out using other alternatives based upon the fitting of the first two terms of a power series. Then a linear regression analysis is made to represent these data into an equation of the form:

$$y = a_0 + a_1 x \tag{2}$$

The CO_2 emissions data is analysed by performing Eq. (2), which is an analysis that tries to predict the future movements based on

Table 2
CO_2 emissions by countries from 1971 to 2007.

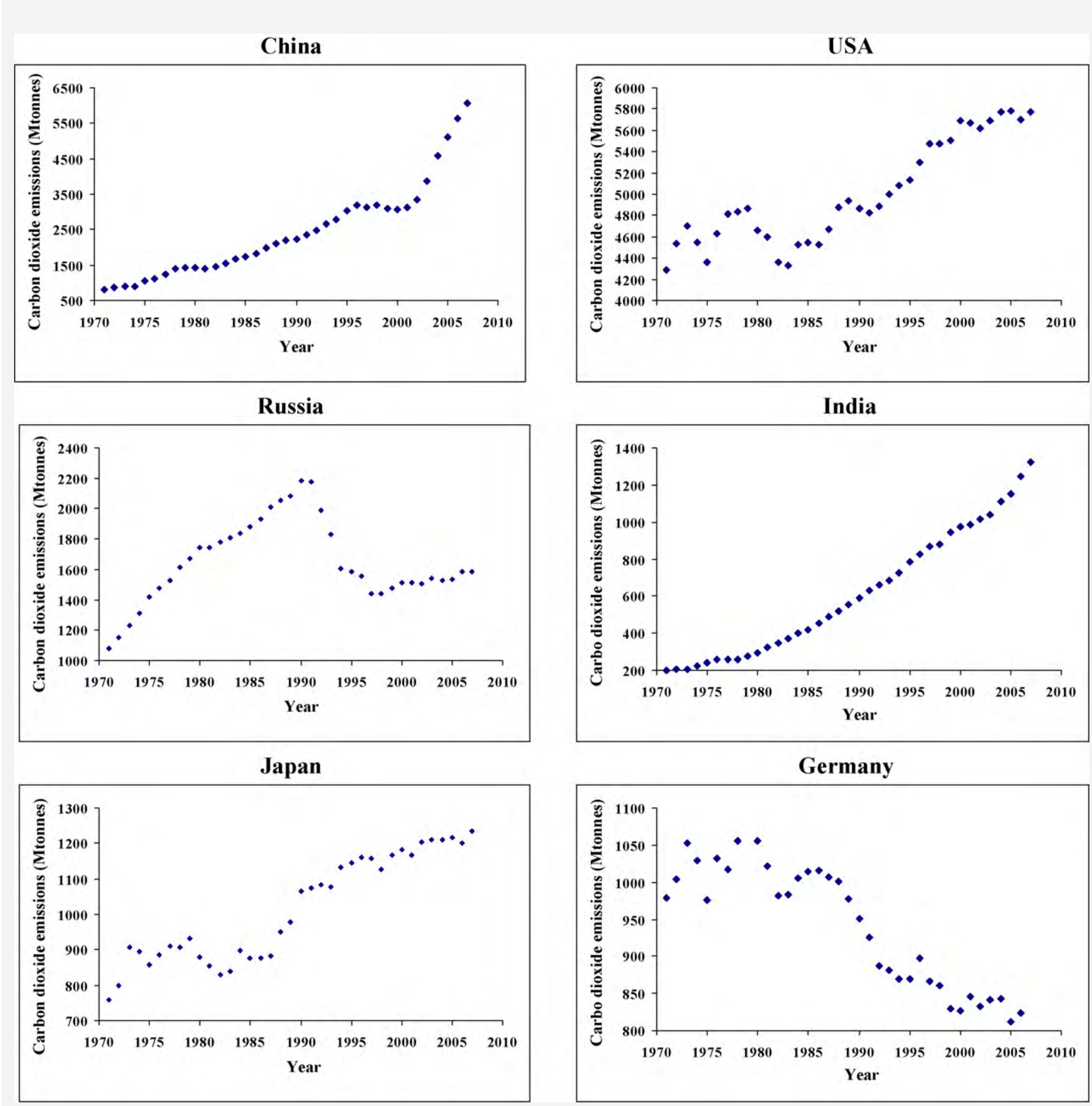


Table 2 (*Continued*)

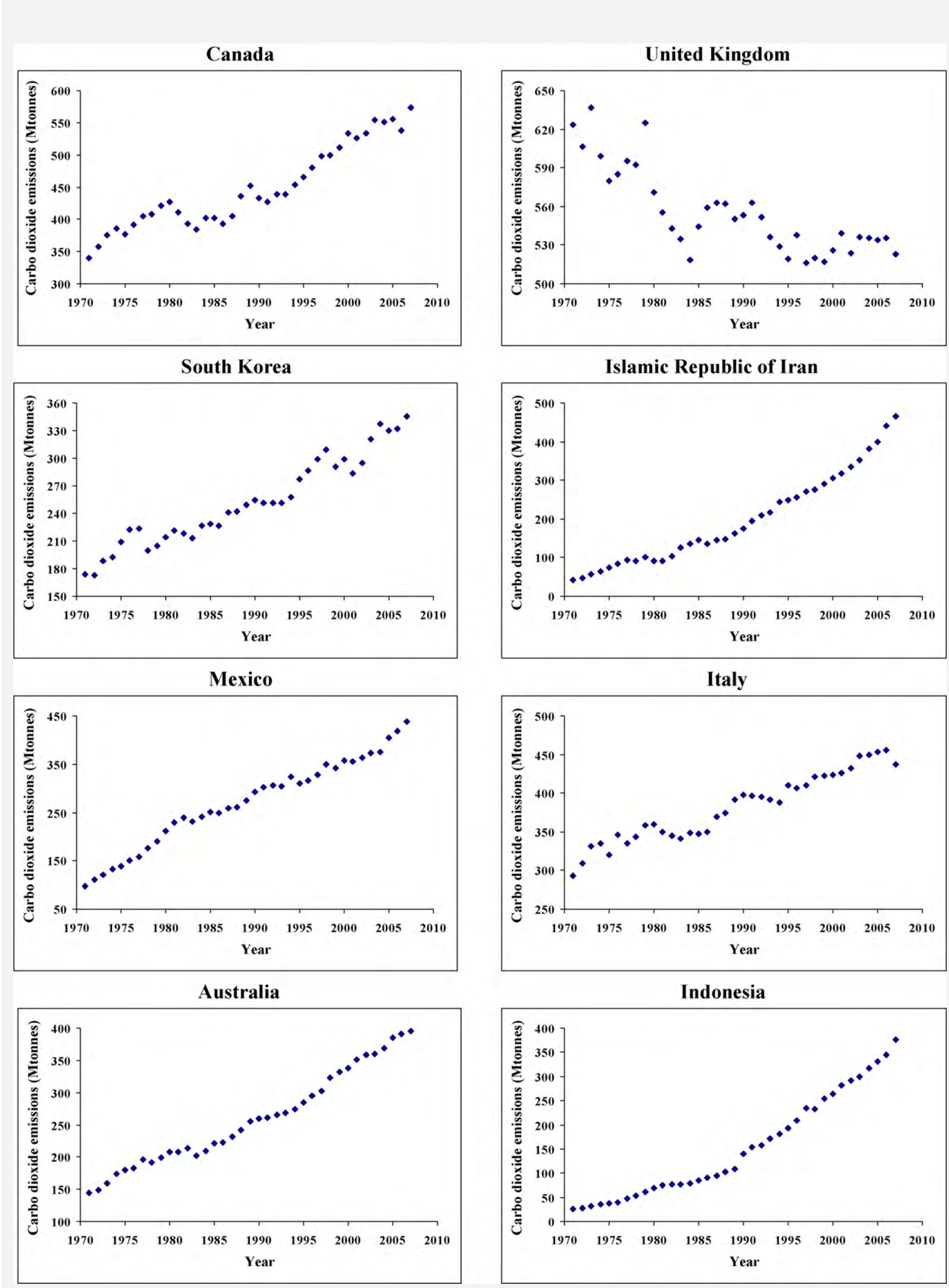


Table 2 (*Continued*)

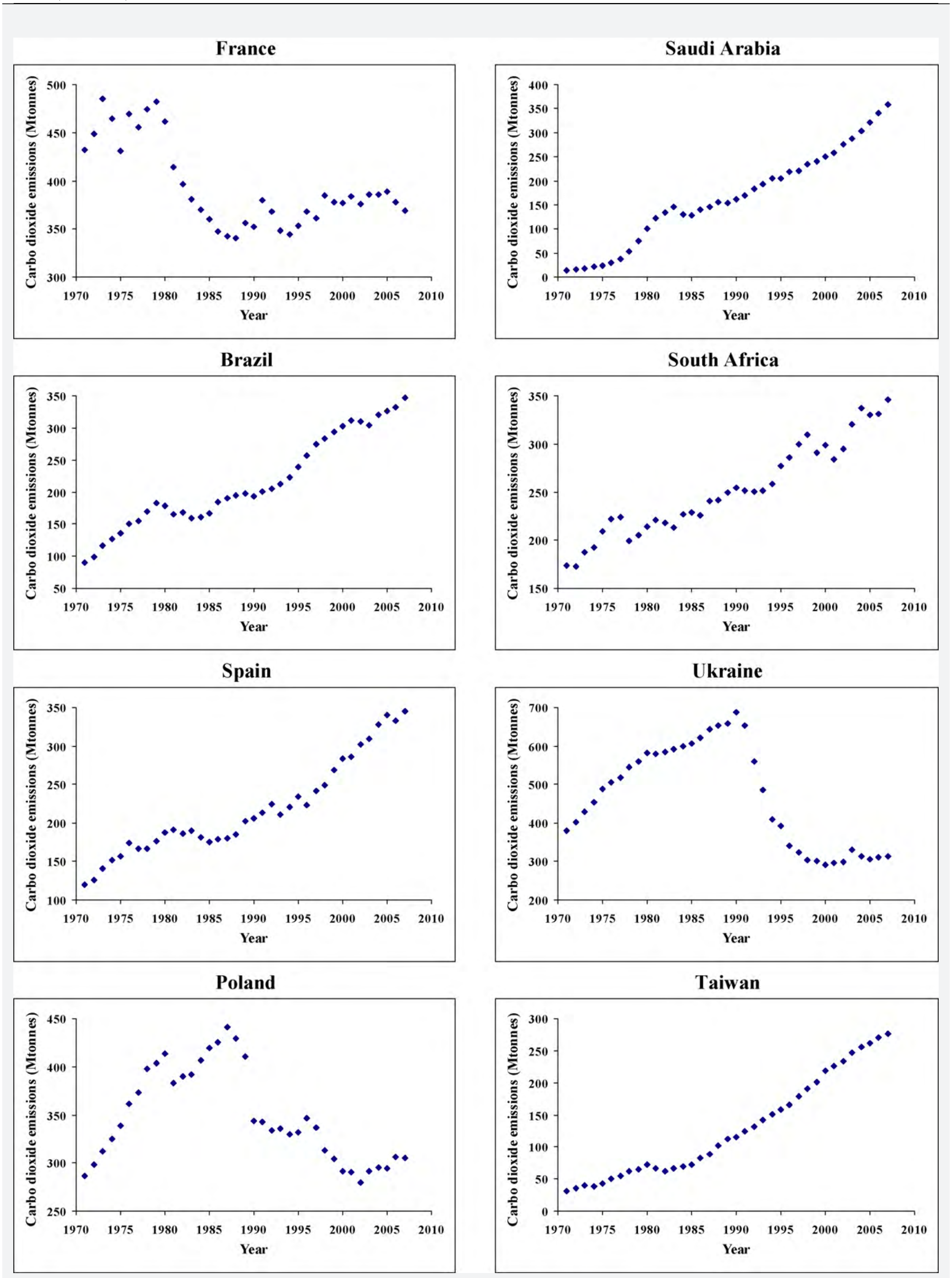
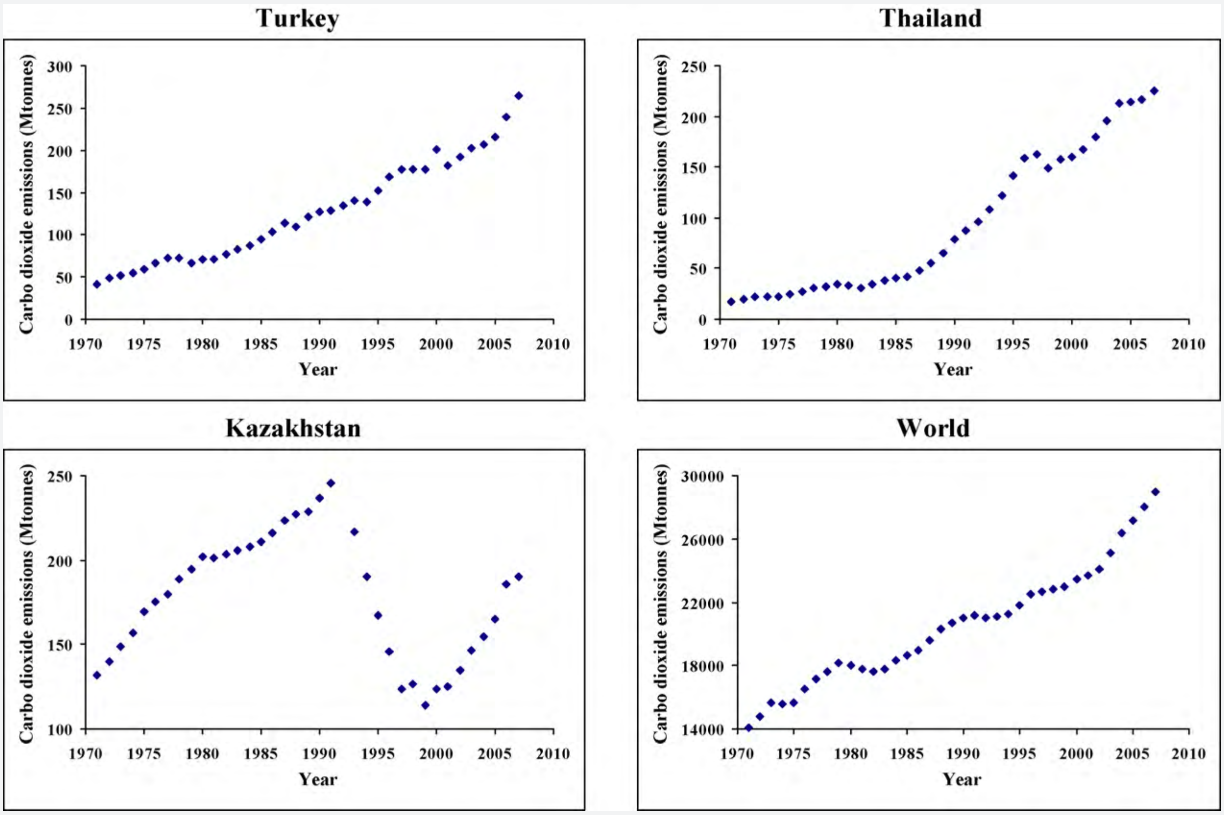


Table 2 (*Continued*)



past data. First some historic data is analysed and presented in a graph.

The goodness of fit of the regression analysis (R^2) is the percentage of variance in the dependent variable projected by the equation. On developing the regression analyses, the regression analyses with R^2 values less than 0.94 showing insignificant influence in statistical tests have been discarded.

3. Regression analysis for future projections

Trend analysis approach has been employed for modelling to forecast of energy-related CO_2 emissions. Top-25 CO_2 emitter's countries and the world total CO_2 emissions over the time period 1971–2007 are plotted in Table 2. As seen from Table 2, fourteen countries CO_2 emissions (China, United States, Russian Federation, Japan, Germany, Canada, United Kingdom, Italy, France, Spain, Ukraine, Poland, Thailand, and Kazakhstan) are not a straight line. There is a drastic change in the rate of CO_2 emission growth for each case. Therefore modelling the CO_2 emissions are not required by trend analysis. On the other hand for eleven countries (India, South Korea, Islamic Republic of Iran, Mexico, Australia, Indonesia, Saudi Arabia, Brazil, South Africa, Taiwan, and Turkey) and the world total CO_2 emissions are fitted as a straight line for each case. Therefore those eleven countries and world total CO_2 emissions are projected.

The CO_2 emissions for eleven countries and world total CO_2 emissions (CO_2) correlation versus the year (Y) was obtained from modelling with the fit coefficients and R^2 values for each fitting are given in Table 3. All the regression analysis given in Table 3 has been carried out using EViews 5.0 package [29].

In order to ascertain the accuracy of the regression analyses is given in this study, the following procedures have been adopted.

Firstly, the coefficient of determination (R^2 values) associated with all regression analyses has been evaluated, which are also indicated along with the statistics of each analysis. The R^2 values depict good regression analysis fits.

Secondly, the plots comparing the actual CO_2 emissions of each country with the regression analysis estimation have been verified. The plots illustrate acceptable levels of accuracy of these regression analyses. Plots relevant to the regression analysis between actual CO_2 emissions are given in Table 4.

The goodness of all fittings in all regression analysis (R^2) is good. It changes between the value 0.9783 and 0.9400.

A $100\,(1-\alpha)$ percent confidence interval on new fitted value for CO_2 emissions, y_{new}, is obtained as follows [30]:

$$y_{\text{new}} \pm t_{\alpha/2,n-2}\sqrt{\hat{\sigma}^2\left(1+\frac{1}{N}+\frac{(x_{\text{new}}-\bar{x})^2}{\sum_{i=1}^{N}(x_i-\bar{x})^2}\right)} \tag{3}$$

Table 3
Regression analyses for (1971–2007) by country ($R^2 \geq 0.94$).

Country	$CO_2 = A + BY$ CO_2 (Mtonnes)	R^2
India	$CO_2 = -60{,}563.637 + 30.758Y$	0.9664
South Korea	$CO_2 = -27{,}124.604 + 13.764Y$	0.9590
Islamic Republic of Iran	$CO_2 = -20{,}911.057 + 10.613Y$	0.9473
Mexico	$CO_2 = -16{,}429.691 + 8.396Y$	0.9783
Australia	$CO_2 = -13{,}137.268 + 6.7356Y$	0.9733
Indonesia	$CO_2 = -18{,}834.861 + 9.546Y$	0.9459
Saudi Arabia	$CO_2 = -17{,}720.441 + 8.992Y$	0.9760
Brazil	$CO_2 = -12{,}643.307 + 6.464Y$	0.9416
South Africa	$CO_2 = -8296.972 + 4.298Y$	0.9400
Taiwan	$CO_2 = -13{,}904.660 + 7.055Y$	0.9481
Turkey	$CO_2 = -10{,}775.345 + 5.481Y$	0.9627
World total	$CO_2 = -655{,}006.897 + 339.619Y$	0.9568

where $\hat{\sigma}^2$ is the standard deviation, N is the number of observation, $t_{\alpha/2,n-2}$ is degrees of freedom. Degrees of freedom value is read from a student t table [31].

Using Eq. (3), confidence intervals were calculated for each regression analysis for 95% confidents.

The calculated results for CO_2 emissions from fitted curves for each country with confidence intervals and the projected CO_2 emissions calculated from "high economic growth case scenario", "reference case scenario" and "low economic growth case scenario" [8] are presented in Table 5. As seen from Table 5, the projected CO_2 emissions are expected to increase in 2007–2030 for all countries based on trend analysis. Those projected increase present a particular challenge to regressed countries of the Kyoto Protocol, which are committed to reducing their emissions by the budget period 2008–2012.

The trend analyses, which were carried out for eleven countries and world total CO_2 emissions from the consumption of all fossil fuels (petroleum, flaring of natural gas, natural gas, and coal), have given close results to the expectations in International Energy Outlook 2009 for the countries namely India, South Korea, Mexico, Australia, Brazil and world total CO_2 emissions where the projected data available from "high economic growth case scenario", "reference case scenario" and "low economic growth case scenario" respectively.

World total CO_2 emissions with the high economic growth case, reference case and low economic growth case scenarios are 8.3%, 6.1% and 3.9% greater than the calculated world total CO_2 emissions with the upper level in for the projected year 2015 respectively. While world total CO_2 emissions with the high economic growth case, reference case and low economic growth

Table 4
Actual and correlated CO_2 emissions by countries (1971–2007).

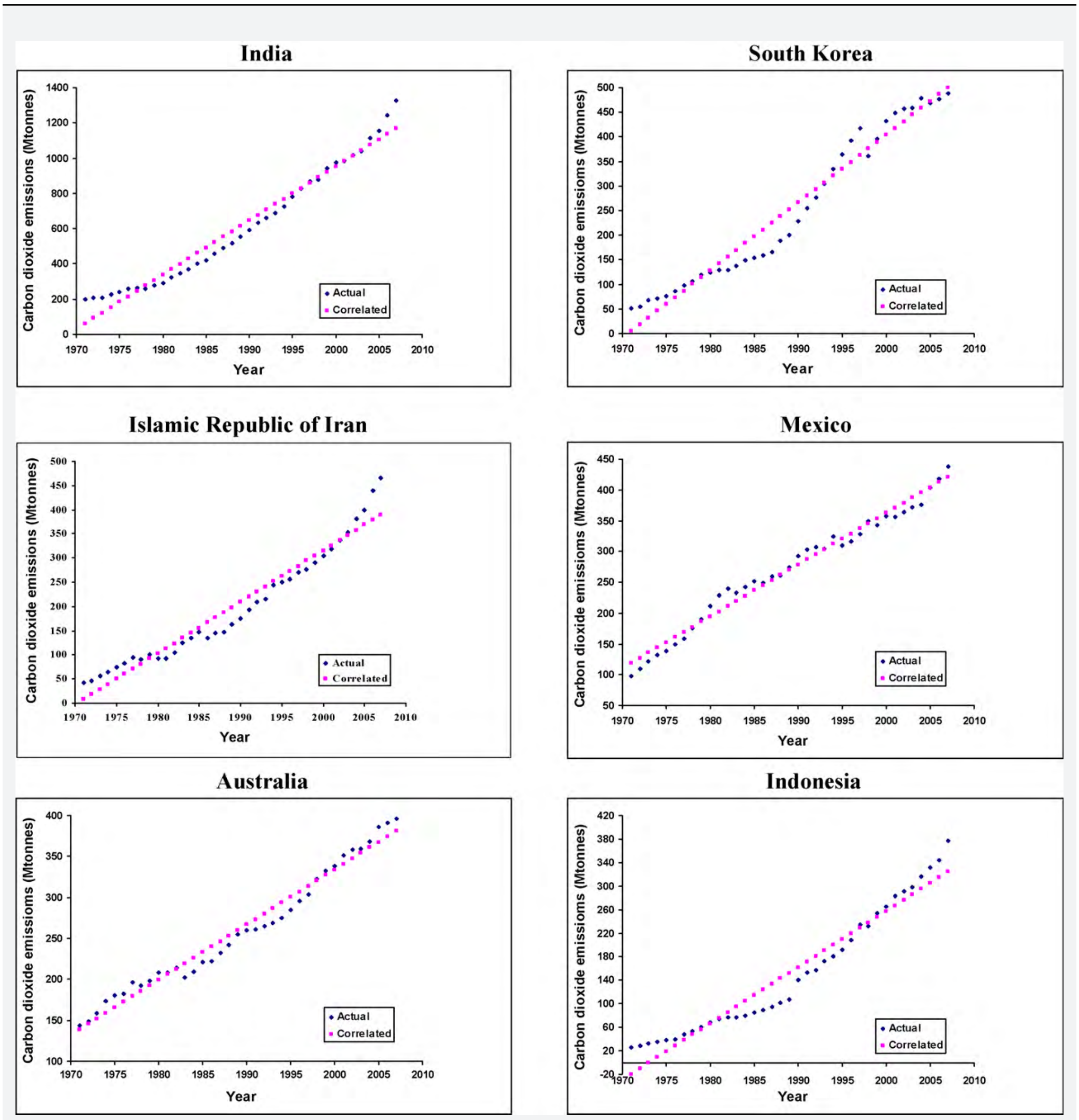


Table 4 (*Continued*)

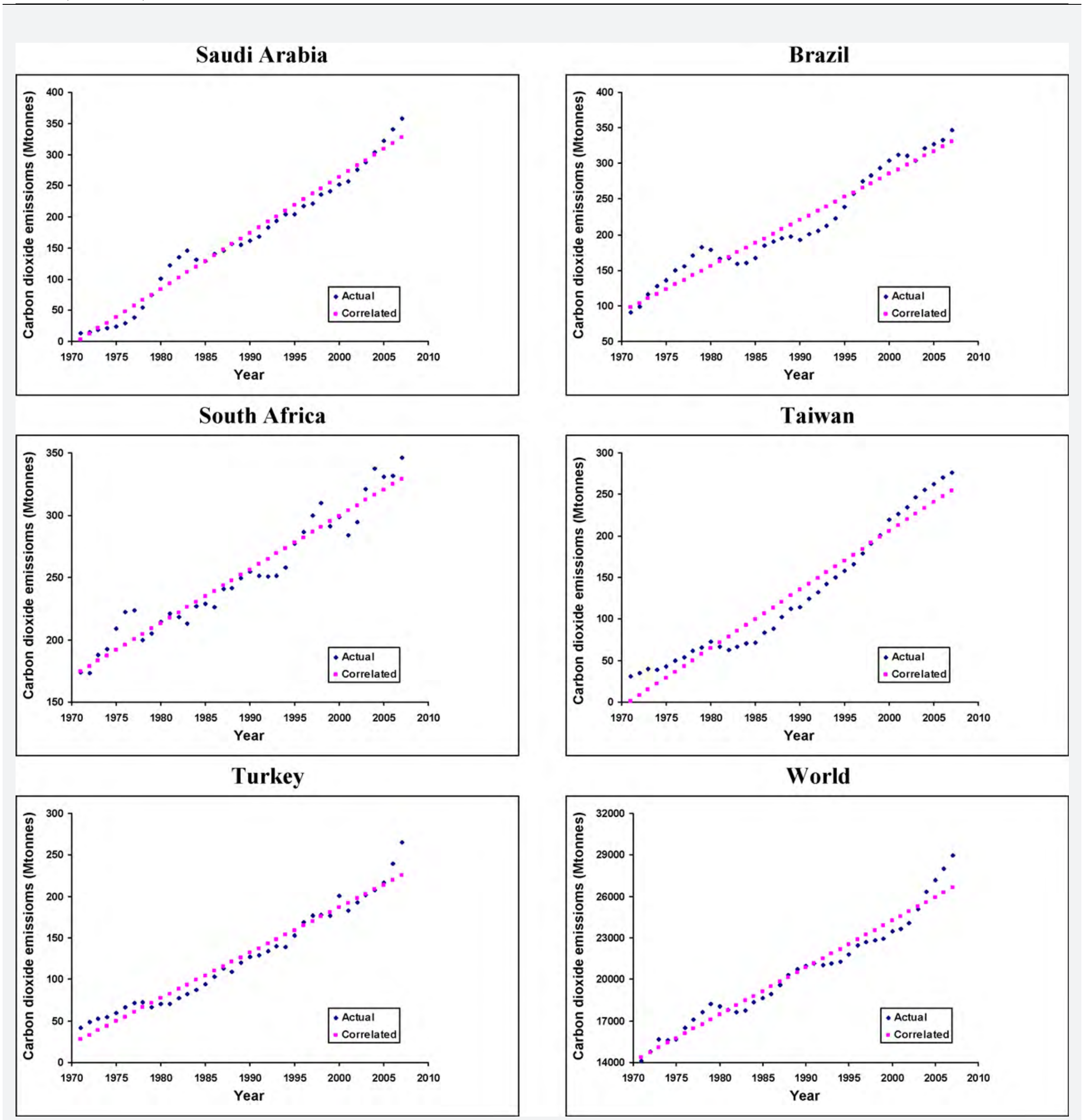


Table 5
Projected CO_2 emissions by country with confidence intervals (Mtonnes of CO_2).

Country	2015	2030	2015 HEG/REF/LEG	2030 HEG/REF/LEG
India	1413.73 ± 139.4	1875.10 ± 152.6	1611/1572/1535	2316/2115/1932
South Korea	609.86 ± 69.1	816.32 ± 75.7	630/614/599	753/680/614
Iran	474.14 ± 60.8	633.33 ± 66.6		
Mexico	488.25 ± 30.4	614.19 ± 33.3	424/414/403	611/557/508
Australia	434.97 ± 27.1	536.00 ± 29.7	478/469/461	574/530/489
Indonesia	400.33 ± 55.5	543.52 ± 60.7		
Saudi Arabia	398.44 ± 34.3	533.32 ± 37.6		
Brazil	381.65 ± 39.1	478.61 ± 42.9	506/488/470	778/682/597
South Africa	363.50 ± 26.4	427.97 ± 28.9		
Taiwan	311.16 ± 40.2	416.99 ± 44.0		
Turkey	268.87 ± 25.1	351.09 ± 27.5		
World total	29,325 ± 1752	34,420 ± 1918	33,896/33,111/32,325	44,108/40,385/36,930

HEG: high economic growth case, REF: reference case, LEG: low economic growth case.

case scenarios are 17.6%, 10.0% and 1.6% greater than the calculated world total CO_2 emissions with the upper level value for the projected year 2030 respectively. Approximately same deviations exit for the other regressed countries (see Table 5).

The deviations between the calculated results in this study and the data available in International Energy Outlook 2009 come from the applied scenarios to CO_2 emissions calculation in International Energy Outlook 2009. This is an expected result because of the all scenarios in International Energy Outlook 2009 use the different annual percent growth for energy consumption in the CO_2 emissions calculation.

In the CO_2 emissions projection period from 2006 to 2015, the world energy use increases by an average of 1.5%, 1.7% and 2.0% per year in the International Energy Outlook 2009 for low growth rate, reference and high growth case projections. In the later years of the projections the worldwide energy demand growing by 1.0%, 1.4% and 1.8% per year between 2015 and 2030 in the International Energy Outlook 2009 for low growth rate, reference and high growth case projections.

Economic growth is the most significant factor underlying the projections for growth in energy-related CO_2 emissions in the mid-term, as the world continues to rely on fossil fuels for most of its energy use. Accordingly, projections of world CO_2 emissions are lower in the International Energy Outlook 2009 low economic growth case and higher in the high economic growth case.

In the high growth case, world CO_2 emissions increase at an average rate of 1.8% annually from 2006 to 2030, as compared with 1.4% in the reference case. For the OECD countries, the projected average increase in the high growth case is 0.6% per year; for the non-OECD countries, the average is 2.6% per year. In the low growth case, world CO_2 emissions increase by 1.0% per year from 2006 to 2030, with averages of 0.1% per year for the OECD countries and 1.8% per year for the non-OECD countries. In 2030, total energy-related CO_2 emissions worldwide range from a projected 36,930 Mtonnes in the low growth case to 44,108 Mtonnes in the high growth case 19.4% higher than projected in the low growth case (see Table 5).

We believe that a full understanding of energy trends under current laws and policies requires consideration of the uncertainties. Actually, rates of improvement in CO_2 intensity could vary considerably in the future, based on economic growth rates, technological progress, and political initiatives.

4. CO_2 emissions reductions

Today the concept of sustainable development is widely accepted and the need to integrate economic, environmental and social aspects within development policies is progressively recognized in many developed countries.

In order to analyse whether the current development in the world can be called sustainable it is necessary to consider the second requirement, namely the negative impact on environment of the current energy production and consumption, too. Currently the energy sector has a considerable negative impact on the environment. First of all, the combustion of fossil fuels cause climate change and air pollution. Secondly, the extraction and transport of the fossil fuels has a big negative impact on the surrounding environment. Lastly, the amount of fossil fuels left are finite, hence the current major energy use does influence the ability of future generations to meet their needs. Considerable amount of fossil fuels in energy consumption must be replaced by nuclear energy and renewable sources of energy to reducing CO_2 emissions in the world. Since nuclear energy and renewable sources of energy already contribute to reducing CO_2 emissions. Besides use of nuclear energy and renewable sources of energy, there are also several broad methods like more efficient conversion of fossil fuels, switching to low-carbon fossil fuels and suppressing emissions and decarbonisation of fuels and flue gases, and CO_2 sequestration for mitigation of CO_2 emissions [32].

Renewable energy sources that use indigenous resources have the potential to provide energy services with zero or almost zero emissions of both air pollutants and greenhouse gases. Renewable energy sources have enormous potential and can meet many times the present world energy demand. They can enhance diversity in energy supply markets, secure long-term sustainable energy supplies, and reduce local and global atmospheric emissions. They can also provide commercially attractive options to meet specific needs for energy services create new employment opportunities, and offer possibilities for local manufacturing of equipment. Technological advances offer new opportunities and declining costs for renewable energy technologies which, in the longer term, could meet a greater share of the rapidly growing world energy demand for increasing the use of renewable sources of energy [9,12,32].

Nuclear power is the main source of energy in some of the major developing countries in the world and contributes to almost 5% of the global energy demands [33,34]. As of April 2010, there were 438 nuclear power plants operating in 30 countries around the world and 54 nuclear power reactors are under construction in 15 countries worldwide [35]. Advanced designs are been developed for all types of reactors. The main goals of the designers and manufactures are: to improve the economics of nuclear power, reduce the residual risk of accident, reduce the emissions and residuals, including radioactive waste from the routine operation of nuclear facilities, expand the resource base and broaden the range of applicability of nuclear power [36,37].

In a full energy chain analysis of the alternative ways of producing electricity, which takes into account all energy investments in plant construction and fuel production, hydro, wind and nuclear power, appear very attractive options from the point of view of environmental protection. The emission factors of non-fossil fuel energies which are hydro, wind and nuclear energy, are very low. They are in the range of 0.004–0.025 Mtonnes CO_2/TWh. Those values are about 95–15 times less than the emissions from natural gas power sources, the cleanest fossil fuel available. Full energy chain CO_2 emissions produced by different energy sources are presented in Table 6 [38].

According to the full energy chain CO_2 emissions (see Table 6), specially nuclear energy and also possible renewable sources of energy use must be increased while fossil fuels (coal, oil and natural gas) use must be decreased in energy consumption to reducing CO_2 emissions in the all countries of the world.

In an increasingly competitive and international global energy market, a number of key factors will affect not only the energy choice, but also the extent and manner in which different energy sources are used. These include: optimal use of available resources; reduction of overall costs; minimizing environmental impacts; convincing demonstration and safety; and meeting national and global policy needs. For nuclear energy and other options, these

Table 6
Full energy chain CO_2 emissions produced by different energy sources (Mtonnes CO_2/TWh).

Source	CO_2 emissions
Wind	0.020
Solar	0.200
Hydro	0.004
Nuclear	0.025
Natural gas	0.380
Oil	0.760
Hard coal	0.790
Lignite	0.910

five factors will determine the future of energy mix and strategies, at the national and global levels [39].

5. Conclusions

One of the most important tasks from the point of sustainability is to decouple the economic growth from the environmental impact. Therefore, minimum energy consumption with least cost, which results in least detrimental effect on the environment and also promotes the economic and social development, should be achieved by considering sustainable development principles.

Increased use of fossil fuels as a result of rapid industrialization can be cited as one of the reasons of global warming. Increased international consciousness regarding the long-term implications of global warming has lead to international cooperation in the reduction of greenhouse gas emissions. In this context, it becomes extremely important to measure accurately the greenhouse gas emissions of countries.

This paper has examined first, trends in CO_2 emissions for the top-25 countries and the world total CO_2 emissions during 1971–2007 are identified. On developing the regression analyses, the regression analyses with R^2 values less than 0.94 showing insignificant influence in statistical tests have been discarded. Statistically significant trends are indicated in eleven countries namely, India, South Korea, Islamic Republic of Iran, Mexico, Australia, Indonesia, Saudi Arabia, Brazil, South Africa, Taiwan, Turkey and the world total. The results obtained from the analyses showed that the models for those countries can be used for CO_2 emission projections into the future planning. The calculated results for CO_2 emissions from fitted curves have been compared in the confidence intervals with the projected CO_2 emissions calculated from "high economic growth case scenario", "reference case scenario" and "low economic growth case scenario" [8] respectively. Agreements between calculated results and the projected CO_2 emissions from different scenarios are in the acceptable range.

In the real world, projections for CO_2 emissions are influenced from several factors like fuel consumptions types, technological advances, economic growth rates and political initiatives. For providing more successful and realistic results, projections should be considered together with these additional factors.

References

[1] Yuksel I. Global warming and renewable energy sources for sustainable development in Turkey. Renewable Energy 2008;33:802–12.
[2] Raghuvanshi SP, Chandra A, Raghav AK. Carbon dioxide emissions from coal based power generation in India. Energy Conversion and Management 2006;47:427–41.
[3] The carbon and oxygen cycle 2010; 2010, http://www.envf.port.ac.uk/geog/teaching/environ/sect3-7g.htm [accessed 22.02.2010].
[4] Dunn S, Flavin C. Moving the climate change agenda forward in state of the World 2002, Special World Summit Edition. NY: WW Norton and Company; 2002.
[5] Houghton JT, Meira Filho LG, Callender BA, Harris N, Kattenberg A, Mashell K. Climate change 1995: the science of climate change, intergovernmental panel on climate change. Cambridge: Cambridge University Press; 1996.
[6] Bilgen S, Keles S, Kaygusuz A, Sarı A, Kaygusuz K. Global warming and renewable energy sources for sustainable development: a case study in Turkey. Renewable and Sustainable Energy Reviews 2008;12:372–96.
[7] International Energy Agency (IEA). CO_2 emissions from fuel combustion: annual historical series (1971–2007). Paris: OECD/IEA; 2009.
[8] International Energy Outlook; 2009, http://www.eia.doe.gov/oiaf/ieo/index.html [accessed 22.02.2010].
[9] Mustafa Omer A. Energy, environment and sustainable development. Renewable and Sustainable Energy Reviews 2008;12:2265–300.
[10] Mirasgedis S, Sarafidis Y, Georgopoulou E, Lalas DP. The role of renewable energy sources within the framework of the Kyoto Protocol: the case of Greece. Renewable and Sustainable Energy Reviews 2002;6:247–69.
[11] Erdogdu E. Turkish support to Kyoto Protocol: a reality or just an illusion. Renewable and Sustainable Energy Reviews 2010;14:1111–7.
[12] Asif M, Muneer T. Energy supply, its demand and security issues for developed and emerging economies. Renewable and Sustainable Energy Reviews 2007;11:1388–413.
[13] Sun JW. An alternative viewpoint on the forecasting of energy-related CO_2 emissions in the OECD countries. Energy Policy 2006;34:377–82.
[14] Ramanathan R. An analysis of energy consumption and carbon dioxide emissions in countries of the Middle East and North Africa. Energy 2005;30:2831–42.
[15] He J, Deng J, Su M. CO_2 emission from China's energy sector and strategy for its control. Energy 2009.
[16] Romeo LM, Calvo E, Valero A, De Vita A. Electricity consumption and CO_2 capture potential in Spain. Energy 2009;34:1341–50.
[17] Hatzigeorgiou E, Polatidis H, Haralambopoulos D. CO_2 emissions in Greece for 1990–2002: a decomposition analysis and comparison of results using the Arithmetic Mean Divisia Index and Logarithmic Mean Divisia Index techniques. Energy 2008;33:492–9.
[18] Manoj Panda JP, Ganesh-Kumar A, Vinay Singh V. CO_2 emissions structure of Indian economy. Energy 2009;34:1024–31.
[19] Sharma DP, Nair PSC, Balasubramanian R. Demand for commercial energy in the state of Kerala, India: an econometric analysis with medium-range projections. Energy Policy 2002;30:781–91.
[20] Pokharel S. An econometric analysis of energy consumption in Nepal. Energy Policy 2007;35:350–61.
[21] Erdoğdu E. Electricity demand analysis using cointegration and ARIMA modelling: a case study of Turkey. Energy Policy 2007;35:1129–46.
[22] Ozturk HK, Ceylan H, Canyurt OE, Hepbasli A. Electricity estimation using genetic algorithm approach: a case study of Turkey. Energy 2005;30:1003–12.
[23] Sözen A, Gülseven Z, Arcaklıoğlu E. Forecasting based on sectoral energy consumption of GHGs in Turkey and mitigation policies. Energy Policy 2007;35:6491–505.
[24] Yumurtaci Z, Asmaz E. Electric energy demand of Turkey for the Year 2050. Energy Sources Part A Recovery Utilization and Environmental Effects 2004;26:1157–64.
[25] Tutmez B. Trend analysis for the projection of energy-related carbon dioxide emissions. Energy Exploration & Exploitation 2006;24:139–50.
[26] Dincer I, Dost S, Li X. Energy reality and future projections for Canada. Energy Sources Part A Recovery Utilization and Environmental Effects 1997;3:233–43.
[27] Hofman K, Li X. Canada's energy perspectives and policies for sustainable development. Applied Energy 2009;86:407–15.
[28] Maxvell SC, Delenay HD. Designing experiments and analyzing. Data, Lawrence Erlbaum Association Inc.; 2004.
[29] Quantitative Micro Software (QMS). Econometric Views Package (EViews 5.0). Irvine: Quantitative Micro Software (QMS); 2004.
[30] ReliaSoft Corporation. Life data analysis reference. Tucson, AZ: ReliaSoft Publishing; 2005.
[31] Damodar NG. Essentials of econometrics. New York: McGraw Hill; 2009.
[32] Sims REH, Rogner H-H, Gregory K. Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. Energy Policy 2003;31:1315–26.
[33] British Petroleum. BP statistical review of World energy; 2009, http://www.bp.com/statisticalreview [accessed 14.03.2010].
[34] International Energy Agency (IEA). Renewable energy information (2009 edition). Paris: OECD/IEA; 2009.
[35] IAEA. PRIS, Power Reactor Information System; 2010, http://www.iaea.org/cgi-bin/db.page.pl/pris.db57.htm [accessed 14.03.2010].
[36] Rashad SM, Hammad FH. Nuclear power and the environment: comparative assessment of environmental and health impacts of electricity-generating systems. Applied Energy 2000;65:211–29.
[37] World Nuclear Association; 2010, http://www.world-nuclear.org/info/inf08.html [accessed 14.03.2010].
[38] International Atomic Energy Agency (IAEA). Choosing the nuclear power option: factors to be considered. Vienna: IAEA; 1998.
[39] Erdoğdu E. Nuclear power in open energy markets: a case study of Turkey. Energy Policy 2007;35:3061–73.